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HANDSURGERY

Midterm functional outcome after dorsal capsular imbrication for posttraumatic instability of the distal radioulnar joint

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Abstract
Introduction The dorsal capsular imbrication of the distal radioulnar joint (DRUJ) which was performed because of posttraumatic dorsal instability showed promising functional results after the first postoperative years. Therefore, we hypothesized that patients after capsular imbrication are characterized by good subjective and functional outcome measurements after a midterm period.
Materials and methods Eleven patients (range 21–50 years of age; median 35 years of age) were examined after capsular imbrication of the DRUJ because of posttraumatic instability with a mean follow-up time of 72 months (range 46–114 months; median 66 months). Examination parameters included the determination of range of motion (ROM), grip strength, pain and functional outcome scores (modified Mayo wrist score (MMWS); Disabilities of the Arm, Shoulder and Hand questionnaire (DASH score)).
Results A mean DASH score of 6.7 (range 0–22.5) and mean MMWS of 91.8 (range 75–100) were measured. Grip strength reached 96.7 % of the contralateral hand. Range of motion reached at least 93.1 % of the contralateral hand. Eight of 11 patients regarded functional outcome and pain reduction as excellent. Six of 11 patients did not recognize a diagnosed instability of DRUJ as such. Ulnar-sided wrist pain was the apparent symptom in these cases.
Conclusions Capsular imbrication of the DRUJ is a reliable and sufficient treatment option in case of posttraumatic dorsal instability. Since DRUJ instability is seldom recognized by the patients as such, a standardised diagnostic algorithm is mandatory to guarantee reliability and efficacy for identifying DRUJ instability.

Keywords Capsular imbrication · Distal radioulnar joint · Instability · Mayo wrist score

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Introduction

Lesions of the distal radioulnar joint (DRUJ) demand close attention since instability of the latter may impair the forearm function significantly [1–3]. Triangular fibrocartilage complex tears (TFCC) which cause instability of the DRUJ happen frequently without concomitant fractures [4]. Stabilising structures of the DRUJ are mainly the interosseous membrane, the TFCC, the bony joint geometry, the DRUJ capsule and the extensor carpi ulnaris tendon [5–10]. The distal radioulnar ligaments are considered as crucial in order to preserve stability of the DRUJ [1, 2, 11–16]. The capsule becomes a decisive stabilising tissue if the TFCC is insufficient [12, 14].

Up to now several reconstructive surgical techniques for the treatment of DRUJ instability have been published [17–28]. The majority of these reconstructions require wide dissections in comparison to the capsular imbrication of the

DRUJ which may rise the postoperative complication rate [23, 29]. Gofton et al. [30] examined four different reconstructive techniques. A capsule suture technique and three different transosseous ligament reconstructions using tendon grafts were evaluated with regard to the DRUJ biomechanics in a cadaver model [17, 18, 25, 30].

The capsular imbrication of the DRUJ proved to be reliable and sufficient in the short term [31]. This surgical technique is reasonably simple and does not compromise osseous structures. Furthermore, this procedure does not jeopardize other reconstructive techniques and may be combined with additional interventions [29].

Therefore, the aim of this study was to examine patients with capsular imbrication after a midterm follow-up period.

We hypothesized that patients after capsular imbrication are characterized by good subjective and functional outcome measurements after this postoperative interval.

Materials and methods

The study design was approved by the institutional ethics committee. All patients gave their written consent to participate in the study. We performed a retrospective analysis of 11 patients (2 females and 9 males) who were treated by capsular imbrication for posttraumatic dorsal DRUJ instability. Patients' mean age was 35.9 years (range 21–50 years of age; median 35 years of age). Inclusion criterium was minimum follow-up of 36 months (range 46–114 months; mean 72.2 months; median 66 months). Exclusion criteria were ulnar positive variance (>2 mm), rheumatoid arthritis, arthritis of the DRUJ, cervical spine operations and any systemic neural or connective tissue disease.

To ensure consistency the same resident who was not part of the surgical team conducted data collection throughout the entire study.

Preoperative symptoms prior to surgery persisted on average 3.8 months (range 1.3–6 months). The most frequent cause of instability was a fall on the outstreched arm (*n* 7). Three patients could not recall a definite trauma in the past. One patient suffered from ulnar-sided pain and loss of power without a specific trauma. Demographic data and distribution of injured hand dominance are illustrated

Table 1 Demographic data

Patient (m/f)	Age (years)	Injured hand (dom./Ø dom.)	Follow-up period (months)	Radiological examination
1 (f)	50	dom.	46	n.p.f.
2 (m)	34	Ø dom.	114	n.p.f.
3 (m)	47	Ø dom.	113	Consolidated elbow fracture
4 (m)	21	Ø dom.	73	n.p.f.
5 (m)	39	dom.	51	Consolidated radius fracture
6 (m)	45	dom.	66	n.p.f.
7 (m)	26	dom.	58	n.p.f.
8 (m)	43	Ø dom.	61	n.p.f.
9 (m)	31	Ø dom.	53	n.p.f.
10 (m)	24	dom.	86	n.p.f.
11 (f)	35	dom.	72	Consolidated forearm fracture

m/f male/female; *dom./Ø dom.* dominant/non-dominant; *n.p.f.* no pathological findings

Table 2 Subjective preoperative clinical symptoms and subjective postoperative evaluation of pain, instability, function and satisfaction

Patient (m/f)	Ranking of subjective preoperative clinical symptoms	Postoperative subjective clinical evaluation			Postoperative satisfaction	
		Pain-reduction	Instability-reduction	Function -ROM, grip strength	Satisfaction	Recommendation of treatment
1 (f)	Crackling	Unchanged	Excellent	Excellent	Yes	Yes
2 (m)	Pain > limited ROM > instability	Better	Unchanged	Better	Yes	Yes
3 (m)	Pain	Excellent	Unchanged	Better	Yes	Yes
4 (m)	Instability > pain	Better	Excellent	Better	Yes	Yes
5 (m)	Pain > instability	Excellent	Unchanged	Excellent	Yes	Yes
6 (m)	Pain	Excellent	Unchanged	Excellent	Yes	Yes
7 (m)	Reduced grip strength > pain > crackling	Excellent	Unchanged	Excellent	Yes	Yes
8 (m)	Reduced grip strength > pain > instability	Excellent	Excellent	Excellent	Yes	Yes
9 (m)	Pain > limited ROM	Excellent	Unchanged	Excellent	Yes	Yes
10 (m)	Pain > reduced grip strength	Excellent	Unchanged	Excellent	Yes	Yes
11 (f)	Pain > reduced grip strength	Excellent	Unchanged	Excellent	Yes	Yes

m/f male/female; *ROM* range of motion

Table 3 Objective outcome measurements

Patient (m/f)	DASH-score	MMW-score	Grip strength compared to healthy side (%)	Anterior-posterior stress test (grading 0–III)	Push off test
1 (f)	7.5	100	105	0	n.p.f.
2 (m)	22.5	80	68	0	Painful
3 (m)	13.5	85	81	0	n.p.f.
4 (m)	10	75	66	I	Painful
5 (m)	1.75	100	96	0	n.p.f.
6 (m)	0	90	113	I	n.p.f.
7 (m)	1.75	100	110	I	n.p.f.
8 (m)	0	100	101	0	n.p.f.
9 (m)	5.25	90	90	0	n.p.f.
10 (m)	0	100	143	0	n.p.f.
11 (f)	11.75	90	90	I	Painful

m/f male/female; *DASH* Disabilities of the Arm, Shoulder, and Hand questionnaire; MMWS Modified Mayo Wrist Score; *n.p.f.* no pathological findings

Table 4 Anterior-posterior stress test: grading of the DRUJ instability

Grading	Description
0	Normal stability
I	Increased laxity, no symptoms elicited during pronation/supination
II	Increased translation, symptoms elicited during pronation/supination
III	Subluxation during active forearm pronation/supination

in Table 1. Subjective preoperative clinical symptoms are outlined in Table 2. Evaluation of the DRUJ instability was performed using the anterior-posterior stress test and push-off test respectively [17, 29, 32, 33]. The severity of instability was graded using the anterior-posterior stress test [32] (Tables 3, 4). Dorsal instability of the DRUJ grade II to III were considered for capsular imbrication.

The follow-up evaluation included clinical examination and questionnaire testing. We assessed functional and subjective parameters. We used a manual goniometer to measure range of motion (ROM). ROM of the operated wrist was compared to ROM of the contralateral wrist (Table 5). We measured grip strength using a calibrated Jamar dynamometer at position 2 (Sammons Preston Pattersol Medical Products, Inc., Bolingbrook, IL). These measurements were done in a standardized manner for both hands. The patients were positioned according to the recommendations of the American Society of Hand Therapists [34]. Each hand was measured 3 times and the mean values were calculated (Tables 3, 6).

Table 5 Range of motion

Motion	Side	Mean (°)	SD (°)	*p* value
Wrist extension	Operated (%)	78.0 (98.9)	9.4	
	Healthy	79.5	12.8	
	Difference	1.5	6.2	0.438
Wrist flexion	Operated (%)	76.3 (97.7)	6.3	
	Healthy	78.4	8.0	
	Difference	2.1	5.2	0.219
Radial deviation	Operated (%)	27.0 (93.4)	6.4	
	Healthy	28.7	4.5	
	Difference	1.7	3.6	0.172
Ulnar deviation	Operated (%)	48.4 (93.1)	10.8	
	Healthy	52.1	10.0	
	Difference	3.7	7.6	0.172
Pronation	Operated (%)	88.8 (97.3)	9.8	
	Healthy	91.5	8.2	
	Difference	3.11	9.4	0.449
Supination	Operated (%)	92.7 (97.0)	9.1	
	Healthy	95.8	6.6	
	Difference	3.1	8.9	0.258

Table 6 Grip strength

Grip strength	Side	Mean (kg)	SD (kg)	*p* value
Grip strength	Operated (%)	46.6 (96.7)	15.7	
	Healthy	49.5	18.4	
	Difference	2.9	11.4	0.465

The patient's opinion regarding preoperative pain, prior subjective instability, range of motion and grip strength were assessed retrospectively and the postoperative outcome was acknowledged with: "excellent", "better", "unchanged" or "worse" (Table 2).

Radiological examination of the wrist was performed preoperatively, as well (Table 1).

Surgical technique of capsular imbrication

The fifth extensor compartment was opened and the extensor digiti minimi tendon was retracted radially. The dorsal joint capsule was exposed and divided longitudinally. Sufficient tissue on the lateral border of the capsule ought to be left to ensure a solid suture technique. Two sutures were applied using FiberWire number 2 (AR-7200; Arthrex, Naples, Florida) to overlap the capsule (Figs. 1, 2). Afterwards the elbow was flexed and the forearm elevated, and after reducing the ulnar head, the capsule was imbricated with the forearm in supination. The sutures were

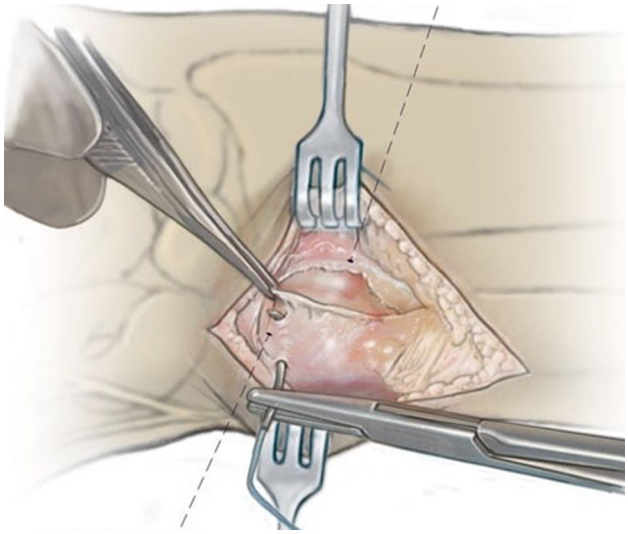

Fig. 1 The ulnar-sided capsule is addressed first using Fiber Wire number 2 (with friendly permission of Springer Science and Business Media)

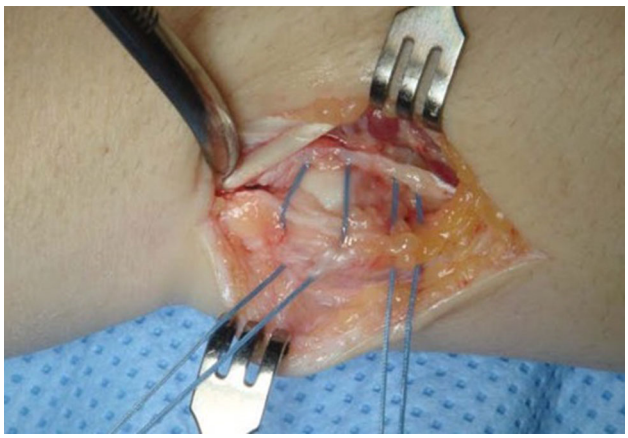

Fig. 2 Two U-shaped sutures are applied properly before reduction and tightening (with friendly permission of Springer Science and Business Media)

tightened, which resulted in a capsular imbrication. This stabilized the ulna in its physiological position. To tighten the imbrication, we used an additional running suture with a 4-0 absorbable material. Each patient received a long-arm cast with the forearm in supination for 4 weeks. Then a Bowers splint was applied for 4 weeks in order to limit forearm rotation [29, 31].

Statistical methods

All variables were analysed descriptively by tabulation of the measures of the empirical distributions. According to the level of the variables, means and standard deviations or absolute and relative frequencies were reported, respectively.

We evaluated possible differences between groups using the Chi-square test in case of categorical variables or Wilcoxon *U* test in case of continuous variables. Possible differences between patients were evaluated by 1-sample *t* tests. For all tests, a *p* value of 0.05 or less.

was considered statistically significant.

Results

Range of motion

No significant difference was detected after surgery regarding range of motion in comparison to the contralateral side (Table 5).

Grip strength

No significant difference was detected after surgery regarding grip strength in comparison to the contralateral side (Table 6).

Modified Mayo Wrist Score (MMWS)

The MMWS was 91.8 for the study population (range 75–100; SD 9.0) (Table 3).

Disabilities of Arm, Shoulder and Hand questionnaire (DASH)

The DASH score of the study population was 6.7 (range 0–22.5; SD 7.2) (Table 3).

Pain

Reduction of pain was regarded as "excellent" by eight patients (72.7 %). Two patients (18.2 %) felt "better" postoperatively and one patient (9.1 %) regarded the postoperative situation as "unchanged" (Table 2).

Subjective instability

Reduction of instability was regarded as "excellent" by two patients (18.2 %). One patient (9.1 %) felt "better" postoperatively and eight patients (72.7 %) regarded the postoperative situation as "unchanged" (Table 2). Six of the latter eight patients did not recognize any instability at all preoperatively whereas two patients considered instability of minor concern (Table 2).

Instability testing (Table 3)

Patient's evaluation

Overall opinion are illustrated in Table 2.

Complications

One (9.1 %) delayed wound healing was observed. Four patients (36.4 %) suffered from postoperative painful sensation during palpation of the DRUJ.

Discussion

Several surgical techniques are published for the treatment of posttraumatic DRUJ instability [17–27]. Petersen and Adams evaluated different procedures in an ex vivo model [35]. The techniques of Eliason [27], Fulkerson-Watson [18], Boyes-Bunnell [36], Hui-Linscheid [20] and Breen-Jupiter [19] were examined regarding their static biomechanical stability and were compared to the physiological articulation. Neither procedure was able to reach the physiological level of stability. Adams and Berger described a surgical procedure using tendon grafts and transosseous fixation between radius and ulna [17]. Fourteen patients were treated by this procedure and were evaluated after mean follow-up of 2,2 years. Wong et al. [23] published a similar suture technique to the one we used. The authors facilitated anchors in order to fix the capsule at the sigmoid notch. Six patients were evaluated after a mean 16 months.

Gofton et al. [30] examined a capsule suture technique and three different transosseous ligament reconstructions using tendon grafts with regard to the DRUJ biomechanics in a cadaver model [17, 18, 25, 30]. The reconstruction of the capsule using the suture technique proved to restore the kinematics of the DRUJ significantly. Moreover, Watanabe et al. [37] could prove that on the one hand the capsule provides significant stability to the DRUJ and that on the other hand capsular imbrication restores stability after compromising DRUJ lesions especially in pronation and supination.

Eleven patients were treated by capsular imbrication because of posttraumatic dorsal instability of the DRUJ. The mean MMWS was 91.8 which is excellent [38, 39]. The surgical technique did not limit range of motion and did not reduce grip strength significantly in comparison to the contralateral side. Grip strength was 96.7 % of the healthy hand which is excellent in comparison to the results published by Adams and Berger [17] who measured 85 % and Wong et al. [23] who reported 80 % [40].

The DASH score was 6.7 overall which is comparative to age-matched healthy individuals [41, 42] and were comparable to the subjective outcome measurements published by Adams and Wong [17, 23]. Postoperative pain levels, subjective function and overall opinion highlighted the above-mentioned good outcome measurements.

DRUJ instability was diagnosed for all 11 patients whereas six patients did not recognize DRUJ instability as such and two patients considered instability of minor concern. Therefore, the clinical appearance of instability is not unequivocal at all [43]. Patients will not regularly identify DRUJ instability as such.

The ulnar-sided wrist pain which exacerbates in pronation and supination is the most frequent symptom [44]. Subluxation of the radius or piano key sign happen rarely [45]. Further symptoms are limited range of motion, diminished strength and subluxation of the extensor carpi ulnaris tendon [19, 20, 46–48]. Simulating the trauma mechanism may often reproduce typical symptoms [3].

A standardised diagnostic algorithm is mandatory to guarantee reliability in order to identify DRUJ instability [3, 49]. Ulna fovea sign, anterior-posterior stress test and press test proved to be efficient [3, 32, 33, 50]. The anterior-posterior stress test and the push off test as a modified press test were used as diagnostic tools for this study. The extent of translation between ulna and radius seems to be decisive for diagnosing DRUJ instability [51].

Moreover, complications were comparable to the studies of Adams and Wong [17, 23].

We applied very strict inclusion and exclusion criteria and very carefully selected our patients to generate the findings as meaningful as possible. Furthermore, the outcome measurements were based on a reasonable follow-up interval. In addition, only 1 examiner who did not belong to the surgical team was commissioned to conducting the examination of our patients, which thus reduced potential variability between different examiners.

The study's weaknesses are its retrospective design and the lack of a control group. Another weakness is that we conducted the study entirely at our clinic, so that patients were mostly from the same region of the country.

All in all, the ulnar-sided wrist pain is the most reported symptom in case of DRUJ instability. Therefore, the former ought to be examined thoroughly and diligently in order to initiate adequate treatment based on the correct diagnosis.

Capsular imbrication proved to be reliable and sufficient in order to treat posttraumatic DRUJ instability. It is reasonably simple and does not jeopardize other reconstructive techniques. Moreover, combination with additional procedures is feasible.

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References

1. Kleinman WB (2007) Stability of the distal radioulna joint: biomechanics, pathophysiology, physical diagnosis, and restoration of function what we have learned in 25 years. J Hand Surg Am 32:1086–1106
2. Hagert E, Hagert CG (2010) Understanding stability of the distal radioulnar joint through an understanding of its anatomy. Hand Clin 26:459–466
3. Spies CK, Muller LP, Oppermann J, Hahn P, Unglaub F (2014) instability of the distal radioulnar joint- an overview of clinical and radiological procedures regarding their efficacies. Handchir Mikrochir Plast Chir 46:137–150
4. Adams BD, Samani JE, Holley KA (1996) Triangular fibrocartilage injury: a laboratory model. J Hand Surg Am 21:189–193
5. Af Ekenstam F, Hagert CG (1985) Anatomical studies on the geometry and stability of the distal radio ulnar joint. Scand J Plast Reconstr Surg 19:17–25
6. Bickel KD (2008) Arthroscopic treatment of ulnar impaction syndrome. J Hand Surg Am 33:1420–1423
7. Siparsky PN, Kocher MS (2009) Current concepts in pediatric and adolescent arthroscopy. Arthroscopy 25:1453–1469
8. Sauerbier M, Hahn ME, Berglund LJ, An KN, Berger RA (2011) Biomechanical evaluation of the dynamic radioulnar convergence after ulnar head resection, two soft tissue stabilization methods of the distal ulna and ulnar head prosthesis implantation. Arch Orthop Trauma Surg 131:15–26
9. Moritomo H (2012) The distal interosseous membrane: current concepts in wrist anatomy and biomechanics. J Hand Surg Am 37:1501–1507
10. Cardenas-Montemayor E, Hartl JF, Wolf MB, Leclere FM, Dreyhaupt J, Hahn P, Unglaub F (2013) Subjective and objective results of arthroscopic debridement of ulnar-sided TFCC (Palmer type 1B) lesions with stable distal radio-ulnar joint. Arch Orthop Trauma Surg 133:287–293
11. Kihara H, Short WH, Werner FW, Fortino MD, Palmer AK (1995) The stabilizing mechanism of the distal radioulnar joint during pronation and supination. J Hand Surg Am 20:930–936
12. Kleinman WB, Graham TJ (1998) The distal radioulnar joint capsule: clinical anatomy and role in posttraumatic limitation of forearm rotation. J Hand Surg Am 23:588–599
13. Palmer AK (1990) Triangular fibrocartilage disorders: injury patterns and treatment. Arthroscopy 6:125–132
14. Ward LD, Ambrose CG, Masson MV, Levaro F (2000) The role of the distal radioulnar ligaments, interosseous membrane, and joint capsule in distal radioulnar joint stability. J Hand Surg Am 25:341–351
15. Shinohara T, Tatebe M, Okui N, Yamamoto M, Kurimoto S, Hirata H (2013) Arthroscopically assisted repair of triangular fibrocartilage complex foveal tears. J Hand Surg Am 38:271–277
16. Schmidle G, Arora R, Gabl M (2012) Ulnar shortening with the ulna osteotomy locking plate. Oper Orthop Trauma 24:284–292
17. Adams BD, Berger RA (2002) An anatomic reconstruction of the distal radioulnar ligaments for posttraumatic distal radioulnar joint instability. J Hand Surg Am 27:243–251
18. Fulkerson JP, Watson HK (1978) Congenital anterior subluxation of the distal ulna. A case report. Clin Orthop Rel Res 131:179–182
19. Breen TF, Jupiter JB (1989) Extensor carpi ulnaris and flexor carpi ulnaris tenodesis of the unstable distal ulna. J Hand Surg Am 14:612–617
20. Hui FC, Linscheid RL (1982) Ulnotriquetral augmentation tenodesis: a reconstructive procedure for dorsal subluxation of the distal radioulnar joint. J Hand Surg Am 7:230–236
21. Tsai TM, Stilwell JH (1984) Repair of chronic subluxation of the distal radioulnar joint (ulnar dorsal) using flexor carpi ulnaris tendon. J Hand Surg Br 9:289–294
22. Scheker LR, Belliappa PP, Acosta R, German DS (1994) Reconstruction of the dorsal ligament of the triangular fibrocartilage complex. J Hand Surg Br 19:310–318
23. Wong KH, Yip TH, Wu WC (2004) Distal radioulnar joint dorsal instability treated with dorsal capsular reconstruction. Hand Surg 9:55–61
24. Leung PC, Hung LK (1990) An effective method of reconstructing posttraumatic dorsal dislocated distal radioulnar joints. J Hand Surg Am 15:925–928
25. Bowers W (1999) The distal radioulnar joint In: Green DP, Hotchkiss RN, Pederson WC (ed) Greeńs operative hand surgery. 4th edn., Philadelphia: Churchill Livingston: 986–1014
26. Noble J, Arafa M (1983) Stabilisation of distal ulna after excessive Darrach's procedure. Hand 15:70–72
27. Eliason EL (1932) An operation for recurrent inferior radioulnar dislocation. Ann Surg 96:27–35
28. Haferkamp H (2012) Kapandji-Sauve procedure with distal radioulnar fusion and segmental resection of the ulna. Oper Orthop Trauma 24:13–22
29. Unglaub F, Manz S, Bruckner T, Leclere FM, Hahn P, Wolf MB (2013) Dorsal capsular imbrication for dorsal instability of the distal radioulnar joint. Oper Orthop Trauma 25:609–614
30. Gofton WT, Gordon KD, Dunning CE, Johnson JA, King GJ (2005) Comparison of distal radioulnar joint reconstructions using an active joint motion simulator. J Hand Surg Am 30:733–742
31. Manz S, Wolf MB, Leclere FM, Hahn P, Bruckner T, Unglaub F (2011) Capsular imbrication for posttraumatic instability of the distal radioulnar joint. J Hand Surg Am 36:1170–1175
32. Seo KN, Park MJ, Kang HJ (2009) Anatomic reconstruction of the distal radioulnar ligament for posttraumatic distal radioulnar joint instability. Clin Orthop Surg 1:138–145
33. Lester B, Halbrecht J, Levy IM, Gaudinez R (1995) "Press test" for office diagnosis of triangular fibrocartilage complex tears of the wrist. Ann Plast Surg 35:41–45
34. Fess EE (1992) Clinical assessment recommendations. In: Casanova JS (ed) Grip strength, 2nd edn. American Society of Hand Therapists, Chicago, pp 41–45
35. Petersen MS, Adams BD (1993) Biomechanical evaluation of distal radioulnar reconstructions. J Hand Surg Am 18:328–334
36. Boyes JH (1970) Bunnell's surgery of the hand, 5th edn. Lippincott Company, Philadelphia (i.a.)
37. Watanabe H, Berger RA, An KN, Berglund LJ, Zobitz ME (2004) Stability of the distal radioulnar joint contributed by the joint capsule. J Hand Surg Am 29:1114–1120
38. Cooney WP, Bussey R, Dobyns JH, Linscheid RL (1987) Difficult wrist fractures. Perilunate fracture-dislocations of the wrist. Clin Orthop Rel Res 214:136–147
39. Green DP, O'Brien ET (1978) Open reduction of carpal dislocations: indications and operative techniques. J Hand Surg Am 3:250–265
40. Klum M, Wolf MB, Hahn P, Leclere FM, Bruckner T, Unglaub F (2012) Predicting grip strength and key pinch using anthropometric data, DASH questionnaire and wrist range of motion. Arch Orthop Trauma Surg 132:1807–1811
41. Jester A, Harth A, Rauch J, Germann G (2010) DASH data of non-clinical versus clinical groups of persons—a comparative study of T-norms for clinical use. Handchir Mikrochir Plast Chirur 42:55–64
42. Klum M, Wolf MB, Hahn P, Leclere FM, Bruckner T, Unglaub F (2012) Normative data on wrist function. J Hand Surg Am 37:2050–2060

43. Hahn P, Wolf MB, Unglaub F (2013) Bilateral test for potential subluxation of the DRUJ. Arch Orthop Trauma Surg 133: 1459–1461
44. Lee SJ, Rathod CM, Park KW, Hwang JH (2012) Persistent ulnar-sided wrist pain after treatment of triquetral dorsal chip fracture: six cases related to triangular fibrocartilage complex injury. Arch Orthop Trauma Surg 132:671–676
45. Bruser P (2004) Ulnar wrist pain. Orthopade 33:638–644
46. Wijffels M, Brink P, Schipper I (2012) Clinical and non-clinical aspects of distal radioulnar joint instability. Open Orthop 6:204–210
47. Wechsler RJ, Wehbe MA, Rifkin MD, Edeiken J, Branch HM (1987) Computed tomography diagnosis of distal radioulnar subluxation. Skeletal Radiol 16:1–5
48. Tsai PC, Paksima N (2009) The distal radioulnar joint. Bull NYU Hosp Jt Dis 67:90–96
49. Iida A, Omokawa S, Akahane M, Kawamura K, Takayama K, Tanaka Y (2012) Distal radioulnar joint stress radiography for detecting radioulnar ligament injury. J Hand Surg Am 37:968–974
50. Tay SC, Tomita K, Berger RA (2007) The "ulnar fovea sign" for defining ulnar wrist pain: an analysis of sensitivity and specificity. J Hand Surg Am 32:438–444
51. Pirela-Cruz MA, Goll SR, Klug M, Windler D (1991) Stress computed tomography analysis of the distal radioulnar joint: a diagnostic tool for determining translational motion. J Hand Surg Am 16:75–82